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ART. XXX.—*On the Heat in the Sun's Rays*; by ELISHA FOOTE.

(Read before the Amer. Association for the Advancement of Science, Aug. 23, 1856.)

THE experiments here detailed were instituted for the purpose of investigating the heat in the Sun's rays.

Two instruments have been used for this purpose. One was Leslie's differential thermometer. Both bulbs of it were blackened by holding them in the smoke of burning pitch. When experimenting one was shaded, the other was exposed to the direct action of the sun's rays; and as both were thus equally subject to all other influences, the result was not affected by them.

Generally, however, I have found it more convenient to use two mercurial thermometers, and note their difference. Two small and very delicate instruments were procured as nearly alike as possible. The stems of both were attached to the same plate about two inches apart, and the scales were marked upon it in juxtaposition, so that the eye could see the indications of both at the same time. Both bulbs were blackened as in the other instrument. It was used in the same manner. The temperatures in the sun and in the shade were noted, and their difference was taken as equivalent to the indications of the differential thermometer.

The question that first arises is, does the difference between the shaded and exposed bulbs afford a correct measure of the heat in the sun's rays? To this point I would ask attention before proceeding to the experiment.

The theory of the differential thermometer was accurately investigated by Leslie. In one of the foci of two parabolic reflectors he placed a tin canister which was heated or cooled by putting in liquids of different temperatures or frigorific mixtures. In the other, the heat was received on one of the bulbs of his differential thermometer: and under all circumstances, the indications of the instrument were found to be accurately proportional to the differences between the temperatures of the canister and those of the surrounding air.

I have varied these experiments by keeping the canister at the uniform heat of boiling water in different temperatures of the air, and by substituting other sources of heat, and have always found the results to accord with those obtained by the distinguished philosopher to whom I have referred.

The principles of radiation lead to the same result; for while the differential thermometer receives heat from the canister, it at the same time radiates it to surrounding bodies, and that in proportion or nearly so to the difference between its temperature and that of the medium in which it is placed.

I regard it therefore as well established that the differential thermometer affords a correct measurement of the *differences* between the heat of the canister and that of the surrounding air. These differences may evidently be varied in two ways: by changing either—

1st. The heat of the canister ; or—

2dly. The temperature of the air.

An increase or diminution in the heat of the canister would directly increase or diminish the differences; whilst an increase in the temperature of the air would diminish the difference until an equality between the two was obtained. If the temperature of the air were uniform and the changes were those of the canister alone, the instrument measuring the differences would correctly indicate those changes. But if the heat of the canister were uniform and that of the air were varied, then would the instrument equally indicate those changes, but in a contrary direction. In case the heat of both the canister and the air was varied at the same time, if we knew the change in one and its effects upon the instrument, we could *easily* deduce the changes in the other. Suppose, for example, an increase of ten degrees on the scale of the instrument and an elevation of five degrees in the temperature of the air; the effect of the latter having been to depress the thermometer five degrees, and the canister having not only overcome that effect but increased the indications ten degrees, the sum of the two or fifteen degrees would be the real change which had taken place in the heat of the canister. Had there been a depression in the temperature of the air, it obviously should be subtracted from the indications of the instrument to obtain the desired measurement.

It is upon these principles that I have applied the differential thermometer to measure the comparative heat in the sun's rays. One of its bulbs received their direct action in the same way that it received the rays proceeding from the canister. The temperature of the air was at the same time obtained by a common thermometer. An increase was added to, and a diminution subtracted from, the indications of the instrument to obtain the real changes in the heat of the rays proceeding from the sun.

My first experiment was of the simplest kind. It was a winter's day. The differential thermometer was placed on the outside of a window where the temperature was below the freezing point. The effect measured by the scale (which merely divided the stem into equal parts) was 53°. It was then placed on the inside of the window where the temperature was about 70°, and to my surprise the effect rose to 115°. The experiment was many times repeated with similar results, although varying some in amount from the different degrees of brightness in the sun. The change in the temperature of the air was still to be added, and the conclusion seemed to be irresistible, that the sun's rays in passing into the heated room acquired a temperature that they did not derive from the sun.

The experiment was next repeated with different temperatures of the room, and it was found that the intensity of the rays depended upon the heat of the room. Indeed in the coldest weather in winter I could impart to them a power which belonged to a summer's sun.

At a later period when the circumstances were changed and the heat on the outside had become greatest, the indications of the instrument were reversed. The high temperature of the summer rays was in a great measure lost or dissipated on entering into a cool room. There they had no greater power than had been found at similar temperatures in the winter.

For the purpose of a more accurate investigation of the subject, I procured a glass shade or receiver about ten inches in diameter and twenty-two in height. A copper base was adapted to it with a groove around the outer edge into which the receiver fitted; and when it was filled with dry ashes the point was thereby rendered sufficiently air-tight. It was supported by legs so high that a spirit lamp could be placed under it, and any required temperature given to the air within.

A second receiver of the same size was sometimes used for the purpose of simultaneous comparison. The air within it was cooled by inserting a tin canister filled with frigorific mixtures. The thermometers were supported within the receivers, and thus at the same time the same rays could be tested in the opposite extremes of temperatures.

I subjoin, as an example, the following table (p. 380) containing the results of an experiment made in February last, at eight o'clock in the morning. It was a clear day and the sun shone through a window into the room where the instruments were placed.

The first observation was the temperature of the room and in the sun upon a mercurial thermometer. The lamp was placed under the receiver, and as the temperature of the air was gradually increased, the effect was noted until the heat in the sun had attained the highest limit of the thermometer. The fourth column contains the differences between the thermometer in the shade and the one in the sun. The fifth column shows the true relative heat of the sun's rays at the different temperatures. It was obtained as before explained by adding to the differences the increase in the temperature of the air. Several observations may be made in regard to the results in the table.

No. of obs.	Temp. of air.	Temp. in sun.	Diff.	Relative heat of sun's rays.
1	40	46	6	6
2	44	50	6	10
3	48	56	8	16
4	50	60	10	20
5	54	66	12	26
6	58	70	12	30
7	63	80	17	40
8	70	90	20	50
9	78	100	22	60
10	83	106	23	66
11	88	110	22	70
12	98	120	22	80
13	102	124	22	84
14	108	130	22	90

1st. That the heat in the sun's rays is not uniform, such as would proceed from a great heated body of uniform intensity, nor is it such as was received from the canister, when kept at the same degree of heat, but that it varies and is dependent upon the temperature of the air.

2ndly. That the effects of the sun's rays upon the thermometer at the different degrees of heat in the receiver is the same that has usually been observed at similar temperatures in the open air. It is easy by changing the heat within the receiver, to imitate the power of the sun's rays that has been observed at any time or in any place; indeed at the same time, the same rays may have in one receiver the burning heat of a summer's sun, and in the other only the feeble action of winter.

3dly. It appears that heat does not travel along with the rays of light as has been usually supposed, but that it is received, or parted with, lost or acquired, according to the temperature of the place that the rays illuminate. The same rays that within the receiver have the high intensity belonging to summer, on passing to the outside, are reduced again to a winter's temperature.

In view of these results it seems to me to accord better with the facts to attribute to the sun's rays, perhaps to all light, an action of some kind on such heat as they come in contact with, producing thereby the effects that we have been accustomed to attribute to an enormous temperature in the sun. Each planet may be supposed to possess its own atmosphere of heat: this will be affected by the sun's light as the heat within the receiver was affected; but they need not be frozen by their great distance, nor burned by their near approach to the great luminary.

It becomes an interesting and important enquiry, to ascertain the circumstances that affect the action of light on heat.

One of the most obvious is, that the amount of action depends upon the quantity of light. The clearness of the atmosphere always affects the experiment, making it somewhat difficult to compare observations taken at different times. A strong light obtained by reflection or otherwise, always increased the effect. But the most striking results were obtained by concentrating the rays with a lens. One was placed in the receiver with its focus directed upon an additional thermometer, the second and third columns in the following table contain the temperatures of the air and in the sun, and the fourth, the heat in the focus, while the air in the receiver was heated as before. The atmosphere at the time was not entirely clear.

No. of obs.	Temp. of air.	Temp. in sun.	Heat in focus.
1	76	82	104
2	78	88	114
3	80	90	120
4	84	96	130
5	90	102	138
6	100	110	148
7	104	114	152

The burning glass was then so arranged that being within the receiver its focus was on the outside. The result was as follows:

No. of obs.	Temp. of air.	Temp. in sun.	Heat in focus.
1	44	50	60
2	51	60	60
3	58	68	62
4	62	72	62
5	73	83	60
6	96	106	58

Then the burning glass was placed on the outside of the receiver and so arranged that its focus should be on the inside, and the effect was the same as if both glass and focus had been on the inside.

It will be observed that the effect of the burning glass is simply to increase the results before obtained. Its power depends upon the temperature of the place at which the light is concentrated. That no heat travels with the light is rendered more manifest. The increased temperature of the rays on the inside had no effect at their focus on the outside.

The power of the burning glass seems therefore to depend on two considerations: 1st, the amount of light concentrated, 2ndly, the amount of heat on which it acts.

Those who have heretofore sought its best effects have, it seems to me, too much neglected the latter consideration. Its greatest power is to be obtained by concentrating the greatest amount of light on the highest degree of artificial heat. The combination of the two may perhaps have important practical applications. The chemist may possibly produce new results by adding to the highest resources of artificial heat the powerful agency of concentrated light.

The subject is unfinished, and it is my intention to resume it on some future occasion.

ART. XXXI.—*Circumstances affecting the Heat of the Sun's Rays;* by EUNICE FOOTE.

(Read before the American Association, August 23d, 1856.)

MY investigations have had for their object to determine the different circumstances that affect the thermal action of the rays of light that proceed from the sun.

Several results have been obtained.

First. The action increases with the density of the air, and is diminished as it becomes more rarified.

The experiments were made with an air-pump and two cylindrical receivers of the same size, about four inches in diameter and thirty in length. In each were placed two thermometers, and the air was exhausted from one and condensed in the other. After both had acquired the same temperature they were placed in the sun, side by side, and while the action of the sun's rays rose to 110° in the condensed tube, it attained only 88° in the other. I had no means at hand of measuring the degree of condensation or rarefaction.

The observations taken once in two or three minutes, were as follows:

Exhausted Tube		Condensed Tube.	
In shade.	In sun.	In shade.	In sun.
75	80	75	80
76	82	78	95
80	82	80	100
83	86	82	105
84	88	85	110

This circumstance must affect the power of the sun's rays in different places, and contribute to produce their feeble action on the summits of lofty mountains.

Secondly. The action of the sun's rays was found to be greater in moist than in dry air.

In one of the receivers the air was saturated with moisture—in the other it was dried by the use of chlorid of calcium.

Both were placed in the sun as before and the result was as follows:

Dry Air.		Damp Air.	
In shade.	In sun.	In shade.	In sun.
75	75	75	75
78	88	78	90
82	102	82	106
82	104	82	110
82	105	82	114
88	108	92	120